Government of the Province of Alberta

ALBERTA TECHNICAL COMMITTEE

Report to

THE MINISTER OF MINES AND MINERALS

and the

OIL AND GAS CONSERVATION BOARD

With respect to an experiment proposed by Richfield Oil Corporation involving an underground nuclear explosion beneath the McMurray Oil Sands with the objective of determining the feasibility of recovering the oil with the aid of the heat released from such an explosion.

August, 1959

Government of the Province of Alberta

ALBERTA TECHNICAL COMMITTEE

Report to

THE MINISTER OF MINES AND MINERALS

and the

OIL AND GAS CONSERVATION BOARD

With respect to an experiment proposed by Richfield Oil Corporation involving an underground nuclear explosion beneath the McMurray Oil Sands with the objective of determining the feasibility of recovering the oil with the aid of the heat released from such an explosion.

August, 1959

TABLE OF CONTENTS

		Page
1.	Introduction	1
	Historical Review	1
	Basis of Consideration of the Proposal	5
2.	Outline of the Proposal	7
3.	Description of the Proposed Test Area	12
	General	12
	Geology	14
4.	Nature of Underground Nuclear Explosions	19
5.	The Anticipated Effects of the Proposed Nuclear Explosion	24
6.	Public Safety Aspects of the Test	36
7.	Pre-Shot Requirements	42
8.	Requirements During the Test	44
9.	Post-Shot Requirements	46
10.	Recommendations	50
	References	54

List of Figures

1.	Sketch Map Showing Areas Within a 10 Mile Radius of Proposed Test Site	13
2.	Generalized North-South Geological Cross-Section, McMurray to Pony Creek	15
3.	Schematic Cross-Section of Generalized Geology and the Anticipated Physical Effects of a 9 Kiloton Nuclear Explosion	26

Appendices

1. Letter from Oil and Gas Conservation Board to The Honourable E. C. Manning, July 22, 1958.

2. Letter from Oil and Gas Conservation Board to The Honourable E. C. Manning, October 22, 1958.

3. Statement of the Joint Dominion and Alberta Technical Committee "Pre-Approval Requirements", May 15, 1959, with the following letters attached:
   (a) Letter to Dr. J. Convey from Dr. G. W. Govier, May 22, 1959, outlining proposed details of analyses listed in "Pre-Approval Requirements".
   (b) Letter to Dr. G. W. Johnson from Dr. G. W. Govier, June 19, 1959, amending the "Pre-Approval Requirements".

4. Map showing vegetation in vicinity of test site, Alberta Technical Committee.

5. Dr. D. A. L. Dick, "Some Aspects of Public Health and Safety", Alberta Technical Committee, 603 - 6th Avenue S.W., Calgary, Alberta.

2. to insure that the radioactive products of the fission reaction were effectively confined in an insoluble siliceous slag as had been the case in a test conducted by the United States Atomic Energy Commission in Nevada on September 19th, 1957,

3. to insure that there would be no radioactive contamination of the oil in the oil sands or of any gas produced therefrom, and

4. to insure that there would be no radioactive contamination of the waters contained in the Grand Rapids sand some 250 feet above the McMurray sand or of the waters contained in the Devonian formation underlying the McMurray sand.

(Following further consideration some of these conditions have since been modified. These will be developed in the report.)

The Honourable Mr. Patrick, Minister of Economic Affairs for the Province of Alberta, convened a press conference* on February 13th, 1959, following which the Premier of the Province announced the establishment of an "Alberta Technical Committee" whose function was to study all aspects of the proposal and to advise the Oil and Gas Conservation Board and the Government of the Province as to whether the proposal should be approved and, if so, the conditions which should be attached to the approval.

The Alberta Technical Committee is comprised of the following persons:

Dr. G. W. Govier (Chairman) - Oil and Gas Conservation Board of Alberta - University of Alberta - Chemical Engineer.

Mr. D. R. Craig - Oil and Gas Conservation Board of Alberta - Petroleum Engineer.

Dr. D. A. L. Dick - Department of Public Health - Therapeutic Radiologist.

---

*Report of this conference is available at the office of The Honourable Mr. Patrick.

2. to insure that the radioactive products of the fission reaction were effectively confined to an insoluble siliceous slag as had been the case in a test conducted by the United States Atomic Energy Commission in Nevada on September 19th, 1957,

3. to insure that there would be no radioactive contamination of the oil in the oil sands or of any gas produced therefrom, and

4. to insure that there would be no radioactive contamination of the waters contained in the Grand Rapids sand some 250 feet above the McMurray sand or of the waters contained in the Devonian formation underlying the McMurray sand.

(Following further consideration some of these conditions have since been modified. These will be developed in the report.)

The Honourable Mr. Patrick, Minister of Economic Affairs for the Province of Alberta, convened a press conference* on February 13th, 1959, following which the Premier of the Province announced the establishment of an "Alberta Technical Committee" whose function was to study all aspects of the proposal and to advise the Oil and Gas Conservation Board and the Government of the Province as to whether the proposal should be approved and, if so, the conditions which should be attached to the approval.

The Alberta Technical Committee is comprised of the following persons:

Dr. G. W. Govier (Chairman) - Oil and Gas Conservation Board of Alberta - University of Alberta - Chemical Engineer.

Mr. D. R. Craig - Oil and Gas Conservation Board of Alberta - Petroleum Engineer.

Dr. G. A. L. Dick - Department of Public Health - Therapeutic Radiologist.

---

*Report of this conference is available at the office of the Honourable Mr. Patrick.

Dr. G. Garland - University of Alberta - Geophysicist.

Dr. C. P. Gravenor - Research Council of Alberta - Geologist.

Dr. H. E. Gunning - University of Alberta - Chemist.

Mr. A. F. Manyluk - Oil and Gas Conservation Board of Alberta - Petroleum Engineer.

Mr. Grant MacEwan - M.L.A. - Lawyer. (Mr. MacEwan resigned from the Committee July 8th, 1959).

The Honourable A. R. Patrick - Minister of Economic Affairs, Government of Alberta.

Mr. H. H. Somerville - Deputy Minister of Mines and Minerals, Government of Alberta.

Meanwhile Richfield Oil Corporation representatives had met with officials of the Federal Government and informed them generally of the nature of the proposal. The Federal Government established a "National Technical Committee" to study the aspects of the proposal of Federal concern and to advise the Federal cabinet concerning the desirability of permitting the importation into Canada, and the detonation in Canada, of a nuclear explosive.

The National Technical Committee is comprised of the following persons:

Dr. John Convey (Chairman) - Director, Mines Branch, Department of Mines and Technical Surveys - Chemist.

Dr. A. H. Booth - Occupational Health Division, Department of National Health and Welfare - Physical Chemist. (Radiation Safety Officer)

Dr. G. W. Govier - Oil and Gas Conservation Board of Alberta - University of Alberta - Chemical Engineer.

Dr. W. E. Grummitt - Atomic Energy of Canada, Limited - Chemist.

Dr. J. H. Harrison - Director, Geological Survey of Canada, Department of Mines and Technical Surveys - Geologist.

Mr. A. Ignatieff - Chief, Fuels Division, Mines Branch, Department of Mines and Technical Surveys - Mining Engineer.

Mr. A. F. Manyluk - Oil and Gas Conservation Board of Alberta - Petroleum Engineer.

Dr. M. L. Natland - Manager, Production Research, Richfield Oil Corporation - Geologist.

Dr. Robert J. Uffen - University College, University of Western Ontario - Geophysicist.

The Alberta Technical Committee has had seven meetings during which virtually all aspects of the proposal have been discussed in detail. Richfield Oil Corporation and the Lawrence Radiation Laboratory of the University of California have provided technical consultants and extensive technical reports relating to underground nuclear explosions carried out in Nevada. Members of both the National and the Alberta Technical Committees visited the actual test sites and the underground tunnels associated with the Nevada tests. The Alberta Committee, in cooperation with the National Committee, has directed Richfield Oil Corporation to submit several technical reports and to make available extensive data on the chemical and physical properties of the formations in the Athabasca area[c]. This material has been received[1] and given detailed study. Confirming analyses have been carried out by Canadian organizations including the University of Alberta and the Mines Branch of the Department of Mines and Technical Surveys. The Alberta and National Technical

---

(c) See statement of "Pre-Approval Requirements", Appendix 3.

Committees held one joint meeting and two members of the Alberta Committee being members of the National Committee attended all meetings of the latter.

Since the initial discussions between Richfield Oil Corporation and the Provincial and Federal authorities, Richfield Oil Corporation has been joined in the project by Canada-Cities Service Petroleum Corporation and at least one other oil company is negotiating a partnership arrangement with Richfield Oil Corporation.

Richfield Oil Corporation has submitted a formal application[1.b] to the Oil and Gas Conservation Board, for a licence to drill a nuclear explosive placement well and to carry out the proposed test at the well.

The report prepared by the Alberta Technical Committee reviews the proposal, describes the proposed area and outlines the general nature of an underground nuclear explosion. A detailed treatment of the chemical, radioactive and thermal effects anticipated from the proposed test is given. The public safety aspects and the conditions under which a low yield nuclear explosion could be carried out with safety are also dealt with in detail. The data required to evaluate the test are discussed. The report concludes with the recommendations of the Committee.

Basis of Consideration of the Proposal

In its consideration of the proposal the Alberta Technical Committee has taken the position that

(1) its ultimate concern is with safety to people,

property, plant and animal life and with conservation of natural resources,

(2) the economic feasibility of the proposal is not the concern of the Committee. (A private corporation should be free to spend its own money - so long as there is no hazard to life, property or resources - on research and experiment regardless of the opinion of others on the commercial prospects of the tests.)

(3) the proposal is for a single experimental test, nothing more, and if the test is approved the approval of the test carries no commitment actual or inferred that further tests or that commercial exploitation of the nuclear method would be approved.

2. OUTLINE OF PROPOSAL

To date no commercial method has been developed to produce oil from the McMurray oil sands. Of the area of about 17,000 square miles which is underlain by oil sands only about 2 per cent has a sufficiently small overburden to permit the use of surface mining methods.

One of the main differences between the oil found in the McMurray oil sands and that of the normal oil field lies in its viscosity. The McMurray oil is hundreds of times as viscous[2] as most other oils, a fact which makes it virtually immobile in its underground state. It is this abnormally high viscosity which has prevented its commercial recovery to date.

Many schemes designed to recover the oil from the deep-seated sands, including gas injection, fluid injection and introduction of heat by various methods have been tried but none have so far proven successful.

The scheme proposed by Richfield Oil Corporation is premised on the introduction to the McMurray oil sand of large quantities of heat at reasonable cost by means of a nuclear explosive. It is believed that the heat released by the explosion would be distributed so as to raise the temperature of a large quantity of the oil and reduce its viscosity to the extent that it could be produced to the surface by normal oil field methods.

Richfield Oil Corporation and Associates propose to detonate a nuclear explosive below the base of the McMurray oil sand in about Legal Subdivision 10, Section 32, Township 79,

Range 7, West of the 4th Meridian. The exact location of the test would depend on the results of topographic surveys and would be selected so as to give a line of sight for two miles to facilitate surface motion photography during the test. Richfield Oil Corporation has prepared a report dated July, 1959, covering every aspect of the proposed project including an operations plan[1.b].

A number of pre-shot wells, about six inches in diameter, would be drilled to varying depths to obtain samples and data, such as water occurrence and behaviour, natural temperature gradients, levels of background radioactivity and chemical and physical formation characteristics. Two of these wells would be instrumented for shock time of arrival measurements at the time of the explosion and would be backfilled from bottom to top, probably with cement. Some of the outlying wells would be cased and retained as post-shot observation wells for the measurement of levels of radioactivity, temperature and the like.

Richfield Oil Corporation proposes that the nuclear explosive be detonated at a depth of about 100 feet below the McMurray-Beaverhill Lake contact. The Alberta Technical Committee, however, having regard to all factors, is of the opinion that a better depth would be about 20 feet rather than 100 feet below the contact. In this report the Committee has assumed that the explosion would occur at the 20 foot depth. The placement well for the nuclear explosive would be drilled to a depth of about 50 feet into the Beaverhill Lake formation and completed with 38 inch outside diameter casing. The casing would be

cemented from top to bottom around the outside.

Pre and post-shot radioactivity levels would be measured of surface fluids and formations in close proximity to the placement well and at the nearest communities in the area.

After all safety and security precautions have been taken, including a dummy run, a 9 kiloton explosive (equivalent to 9,000 tons of high explosive or the heat energy of 1,800 tons of coal), properly stemmed, would be detonated approximately 20 feet below the top of the Beaverhill Lake formation. Although no airborne radioactivity is anticipated precautionary monitoring for it would be provided. Arrangements would be made for other measurements which may be of interest to certain scientific or educational groups.

Although the project would be under the general control of a project manager who would likely be a United States Atomic Energy expert, a Canadian should be given overall veto powers over the entire project or any part of it prior to or after the detonation. The handling, assembly, arming, timing and firing of the device[1.h] would be handled by the United States Atomic Energy Commission or contractors responsible to them, whereas the general support activities would be handled by Richfield Oil Corporation.

If the explosive is detonated about 20 feet below the McMurray oil sand a cavity of about 230 feet in diameter would be formed and it would extend about 100 feet into the oil sand.

Several underground nuclear explosions have been detonated in Nevada and detailed reports of these explosions are

available[1.k]. The results of these tests show that underground explosions can be confined to the extent that no radioactivity will reach the surface. Radioactive products are produced; some of them are entrapped in a shell lining the cavity and the balance are dispersed to the surrounding medium and thence into nearby formations by water movement. The chemistry of radioactivity in aquifers and the rate and efficiency with which radioactivity is removed are covered elsewhere in this report as well as in a paper by G. H. Higgins of the Lawrence Radiation Laboratory[1.d].

The detonation would release about 9 trillion calories of heat and other energy of which 25 to 50 per cent would be available in useful form and at a useful temperature. After a time ranging from a few seconds to a few minutes the cavity first formed would be expected to collapse and to fill with rock debris mixed with McMurray oil sand. It is hoped that a large volume of the oil would be heated to a temperature of about 100 degrees Centigrade at which temperature the viscosity of the oil would be sufficiently reduced to render it producible by normal oil field methods. It is not expected that the oil would contain any serious levels of radioactive contamination. However, any oil recovered would be very carefully monitored for radioactivity. If the oil were found to be radioactive and if it could not be adequately decontaminated further production would be delayed until the radioactivity had decayed to a safe level.

After the detonation a series of evaluation wells would be drilled in the vicinity of the test, initially 500 - 700 feet

from the placement well, with follow-up wells closer to the shot point. Formation fluid and rock samples, levels of radioactivity, temperature surveys and electrical logs would be taken on these wells. In drilling the wells provision would be made for a closed drilling fluid system, operable by remote control should this prove necessary. This system would be instrumented for continuous measurement of pressure, temperature and radioactivity levels. Drilling equipment, rock cuttings and cores would also be monitored for radioactivity. Arrangements would have to be made for the handling, storage and disposal of liquid and solid radioactive samples. When the radioactivity has had time to decay to a low level a well would be drilled into the debris filled cavity to determine the success of the test for oil recovery purposes.

3. DESCRIPTION OF TEST AREA

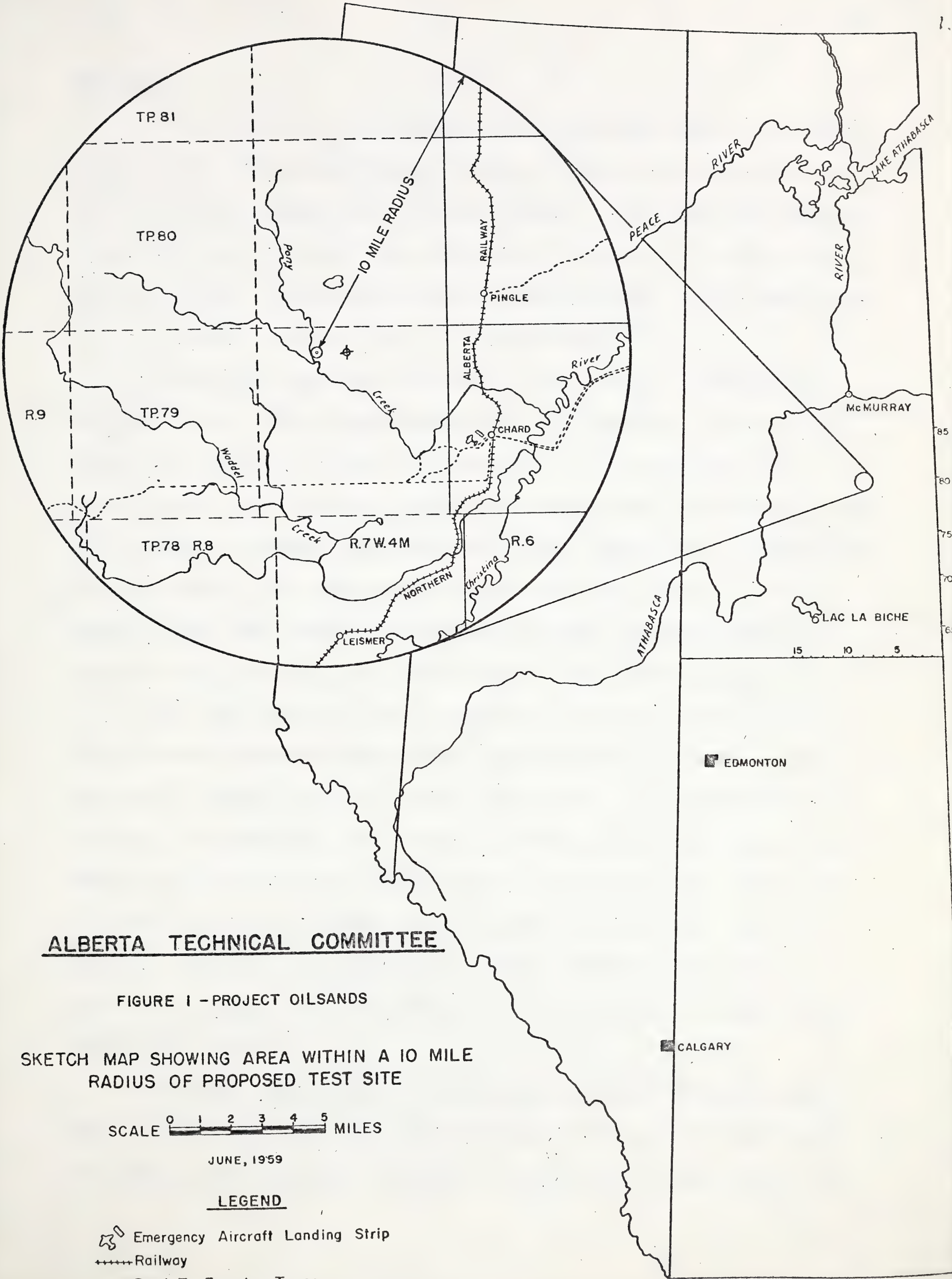
General

The proposed test area is in the southerly portion of the McMurray oil sand deposits, some 65 miles south of the Town of McMurray and 190 miles north-east of Edmonton. A sketch map is presented as Figure 1. On it is shown the location of hamlets, water courses, railroads, roads and trails within a ten mile radius of the site.

The land is gently rolling with muskeg in the lowlands and sandy, low to medium grade soil on the hills and ridges. The area is light to heavily wooded with a few timber stands up to 80 feet in height which are too sparse to be considered for commercial logging operations. The timber is chiefly deciduous, with some black and white spruce and jack pine. There is considerable low brush in the area and the immediate vicinity of the test site is open brush land. Appendix 4 to this report shows the distribution of vegetation found within a ten mile radius of the test site.

Some moose, deer and bear are known to be in the area and marten and beaver may also be found.

The area is sparsely populated, with approximately 12 persons at Chard, 25 at Leismer and about 22 others throughout the remainder of the area. Seasonal and vocational fluctuations occur in the population. No farming is carried out in the area, and, except for experimental work on the oil sands, there are no other mineral developments within 50 miles of the site.



ALBERTA TECHNICAL COMMITTEE

FIGURE 1 - PROJECT OILSANDS

SKETCH MAP SHOWING AREA WITHIN A 10 MILE RADIUS OF PROPOSED TEST SITE

SCALE 0 1 2 3 4 5 MILES

JUNE, 1959

LEGEND

Emergency Aircraft Landing Strip

Railway

Road To Forestry Tower

Trail

Geology

The geology of the McMurray area has been under study for many years. Although surface outcrops along the major rivers have yielded a great deal of data, most of the geologic information has been derived from analyses of hundreds of well cores and cuttings. A detailed study of the geology of the test area has been made by Richfield Oil Corporation[1.c]

The general geologic picture of the area is relatively simple and is shown diagrammatically in Figure 2. The oldest rocks are granite and granite gneisses of Precambrian age. These rocks are found at the surface north-east of McMurray, and are found at increasingly greater depths south-west of McMurray. In the area of the proposed nuclear test the granite lies at about 3,000 feet below the surface, whereas in the Edmonton district the granite lies about 7,000 feet below surface.

After the granites were eroded to a smooth plain, warm seas invaded Alberta and great thicknesses of limestone, shale, dolomite, gypsum, and salt were deposited. In the Edmonton area oil is produced from reefs in these limestones and in the McMurray area the same limestones and dolomites are found outcropping along the Athabasca and Clearwater Rivers. In the area of the test the limestone, shale, dolomite and salt sequence occupies the interval from about 1,200 to 3,000 feet below the surface.

After the deposition of the limestones the McMurray area was uplifted and the seas drained away leaving the limestones exposed to the surface. Thereafter followed a long period of

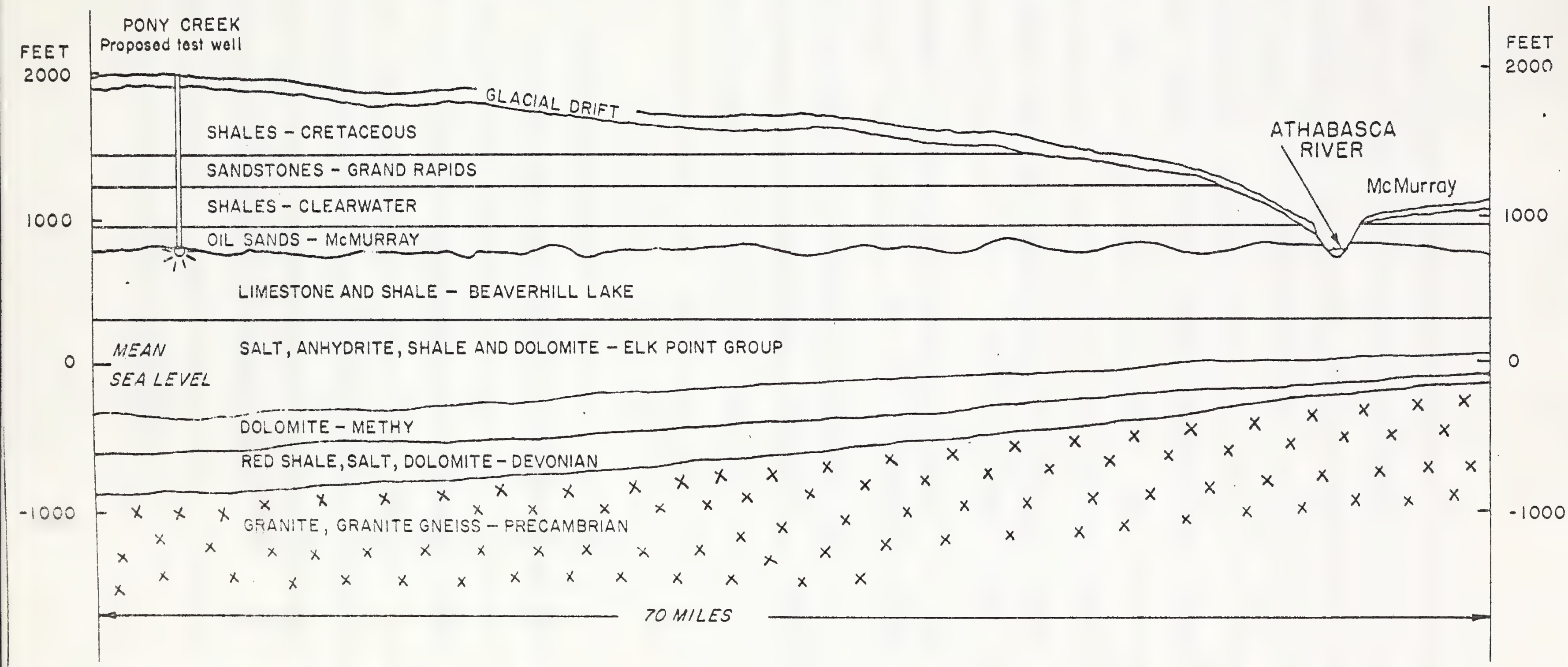


FIGURE 2: GENERALIZED NORTH - SOUTH GEOLOGICAL CROSS-SECTION, McMURRAY TO PONY CREEK

weathering and erosion which left an irregular surface on the top of the limestone. Early in the Cretaceous period fresh-and brackish-water lakes developed on top of the limestones. Sands and clays were washed into these lakes and in some places the sands were "cleaned-up" by the winnowing action of lake currents. This sequence of "clean sands", clays, and mixtures of sand and clay form the McMurray formation. At a later date oil migrated from the south-west into the McMurray formation, saturating the clean sands and giving rise to the world-famous oil sands. The oil is in a highly viscous state - about the consistency of warm tar - and, therefore, cannot be removed by normal oil field recovery methods. The thickness of the oil sands averages about 150 feet, but considerable variation is encountered due to the irregular topography on the underlying limestones. The McMurray oil sand contains approximately 81 per cent silica, 8 per cent oil, 8 per cent water and 3 per cent clay and other mineral matter.

After the deposition of the McMurray formation marine seas of Cretaceous age invaded north-eastern Alberta. Unlike the clear, warm seas of the Devonian the Cretaceous seas were shallow and muddy and as a result thick sequences of clays (shale) and dirty sandstone were deposited on top of the McMurray formation. The shales which immediately overlie the McMurray formation form the Clearwater formation, and the sands which overlie the Clearwater formation, the Grand Rapids formation.

The surface material in the McMurray area is debris which was left by south-westerly moving glaciers.

There are four potential water-bearing horizons in the subsurface: (1) glacial drift, (2) Grand Rapids formation, (3) Basal McMurray formation and (4) the Beaverhill Lake limestone. Of these four there is little known about the hydrologic characteristics of the glacial drift or the Beaverhill Lake limestone. From a study of electric logs of wells in the area it is believed that there is little flow of water in the Beaverhill Lake limestone, although there may be some through joint and bedding planes. From a water quality standpoint the only aquifer of economic importance is the Grand Rapids sandstone and its water is relatively high in total solids, about 2,000 parts per million.

From data obtained through drill stem tests[1.i] it would appear that the pressure in the various aquifers is essentially uniform. This means that very little natural flow of groundwater would be expected except in areas of effluent near the major rivers. This is a normal condition in Alberta subsurface aquifers.

In terms of chemical composition[1.d] the Beaverhill Lake limestone is composed largely of calcium carbonate with minor amounts of silica, alumina, magnesium and iron. The formations above the Beaverhill Lake limestone are siliceous in character, having a low lime content but a relatively high proportion of silica, alumina and iron.

The following log shows the generalized rock sequences with the approximate depths in the area of the proposed test:

Depth below surface		Type of material and age
0 - 220 feet (?) (variable thickness)	-	glacial drift - mainly boulders, clay and unconsolidated sands
220 - 500 feet	-	shales and sandstones of Cretaceous age
500 - 790 feet	-	sandstone - Grand Rapids formation
790 - 1030 feet	-	shale and siltstone - Clearwater formation
1030 - 1200 feet	-	oil-saturated sandstone, siltstone and shale - McMurray formation
1200 - 1620 feet	-	limestone and shale - Beaverhill Lake formation
1620 - 2270 feet	-	salt, ahydrite, shale and dolomite - Elk Point group
2270 - 2500 feet	-	dolomite - Methy formation
2500 - 2830 feet	-	red shale, salt, dolomite of Devonian? age
2830 +	-	granite and granite gneiss of Precambrian age

A detailed lithologic log[3] of the Richfield Pony Creek #2 well which is located about 3 miles from the proposed placement well was prepared by the Research Council of Alberta. The markers and descriptions in this log are based on both samples and cores recovered from the well.

4. THE GENERAL NATURE OF UNDERGROUND NUCLEAR EXPLOSIONS

When a nuclear explosive is detonated underground, energy is transmitted radially to the surrounding rock. This energy is in various forms. Virtually all of our knowledge of the phenomenon of and the distribution of energy in an underground nuclear explosion comes from detailed studies[1.k][4][5] of tests made in Nevada by the Unites States Atomic Energy Commission. These studies have shown that a few months after the detonation about half the energy originally released is in the form of useful heat while the remainder appears as low temperature heat and radioactive particle energy or has been dissipated as long range seismic energy.

A device of 9 kilotons equivalent, which has been suggested for Project Oilsand, would release 9 trillion calories of energy to the earth. This is actually equivalent in total energy to a moderately large earthquake and might at first be expected to produce visible effects of shock vaves over a fairly large area. The effects which would be felt are very much less, however, since half the energy released is quickly transformed into heat and since the shock waves are of a frequency which causes them to be more rapidly scattered and absorbed than in the case of natural earthquakes. The experience from the underground Nevada tests[1.k] suggests that a 9 kiloton device might be felt by observers for distances up to 15 miles. Beyond 15 miles, the shock waves would probably be detectable by instruments only. The Committee is convinced that a nuclear explosion could not

trigger a natural earthquake at the proposed test site which is in a very stable region of the earth's crust.

Immediately after the detonation of an underground nuclear explosive, the temperature within a radius of a few feet becomes so high that the rock is vaporized, forming a vapor cavity. Beyond the vaporized region there is a zone of melted rock. The cavity expands radially with the shock to a radius dependent on the size of the explosion. On cooling, the molten rock solidifies to form a shell-like lining to the cavity, and the majority of the radioactive products of the explosion are at least temporarily entrapped in this shell.

Later the spherical cavity collapses as a result of the weight of the overburden, material falls into it from above, and a "chimney" of broken rock forms upward for a height of $2\frac{1}{2}$ to $3\frac{1}{2}$ times the diameter of the expanded spherical cavity. (For example, in the Rainier test[1.k] in Nevada, involving a 1.7 kiloton explosive, the maximum diameter of the cavity has been determined to have been about 130 feet, while the chimney reached a height of 386 feet from the centre of the detonation.)

It is most important that breakthrough to the earth's surface does not occur so that the radioactive products of the nuclear explosion will be completely confined. The results of five underground tests[1.k] in Nevada, of various energy yield, demonstrate that the safe depth of burial for complete confinement varies with the cube root of the size of the explosive. The depth of burial must exceed the maximum total height of the chimney formed and any vertical fractures extending from its

ceiling. The data indicates that in the Nevada tuff, the chimney itself extends for a height less than 290 times, and the chimney and vertical fractures extend to about 350 times the cube root of the kiloton rating. To be conservative and for safety purposes, the United States Atomic Energy Commission states that the safe depth for complete containment be calcualted from the formula[1.k]

Safe burial depth in feet = 450 times the cube root of the yield of the nuclear explosive in kilotons.

This formula is considered by the Committee to be safe for the conditions in which the Nevada tests were conducted - that is for detonation in a volcanic tuff physically and chemically similar to that of the Nevada test sites.

When crushed rock from overhead falls into the cavity, the initially very high temperatures are quickly reduced. Because of the presence of water in most rock the surrounding material rapidly cools to the temperature of boiling water. Thus, a considerable volume of material is left surrounding the centre of detonation at a temperature near 100 degrees Centigrade. It is this effect which is of direct interest in Project Oilsand.

Radioactive products from the explosion result both from the fission reaction and from the irradiation of elements in the surrounding rock by neutrons emitted during the explosion. In the former category strontium-90 and cesium-137 are the two undesirable long-lived isotopes produced in abundance. If the cavity does not vent or collapse during the first 5 minutes or

so the major portion of the radioactive products, containing 20 - 40 per cent of the strontium-90 and cesium-137, are at least temporarily entrapped in the solidified shell of the cavity. As the bulk of the strontium-90 and cesium-137 have gaseous precursors with half lives of the order of 4 minutes, it may be seen that if the cavity vents or collapses in less than this time a greater proportion of these elements would be deposited on the surfaces of the broken medium filling and surrounding the cavity.

In the Nevada tests, the shell fragments were found to be glass-like and extremely insoluble. For this reason, the United States Atomic Energy Commission reports[1.k][5] state that a large proportion of the radioactive products were permanently and safely sealed in insoluble form. This feature of insolubility is to be expected when the lining is formed chiefly of silica as it was in the Nevada tests. However, in the carbonate rock beneath the oil sands this same degree of insolubility is not to be expected. This is discussed later.

Communicating underground waters contact and dissolve the radioactive products not trapped in the solidifying shell, and will also leach out radioactive material contained in soluble portions of the fused shell. Underground waters tend to move through pores and fractures in the formation and would, therefore, carry these products with them. Laboratory evidence[1.d], partially confirmed by field observations[1.d] indicates that "ion exchange" will take place between the dissolved radioactive

products and the rock minerals which the underground waters contact as they move. In this process, strontium-90, for example, is removed from solution by contact with the rock surfaces.

Through the ion exchange process, one might theoretically deduce that the effective rate of movement of the radioactive products through limestone would be only about 1/400 of that of the underground water itself. In practice, lack of attainment of ion exchange equilibrium and uncertainties and lack of uniformity in the porosity and permeability must be considered so that the best that can be said is that the movement of radioactive products away from their source point would be at a considerably lower rate than the movement of underground waters.

All things considered, it is fair to conclude that all radioactive products can be confined underground by adequate burial depth and that lateral migration of the products by moving underground waters, will be at negligible rates provided the waters themselves are moving slowly.

5. THE ANTICIPATED EFFECTS OF THE PROPOSED EXPLOSION

The specific proposal of Richfield is to detonate a 9 kiloton nuclear explosion at a point approximately 100 feet below the McMurray-Beaverhill Lake contact. As stated in Section 2 of this report, the Alberta Technical Committee believes that 20 feet below the contact is more suitable. This is approximately 1,220 feet below the surface. The following and other discussions in this report assume the nuclear explosive would be detonated 1,220 feet below the surface and 20 feet below the McMurray-Beaverhill Lake contact.

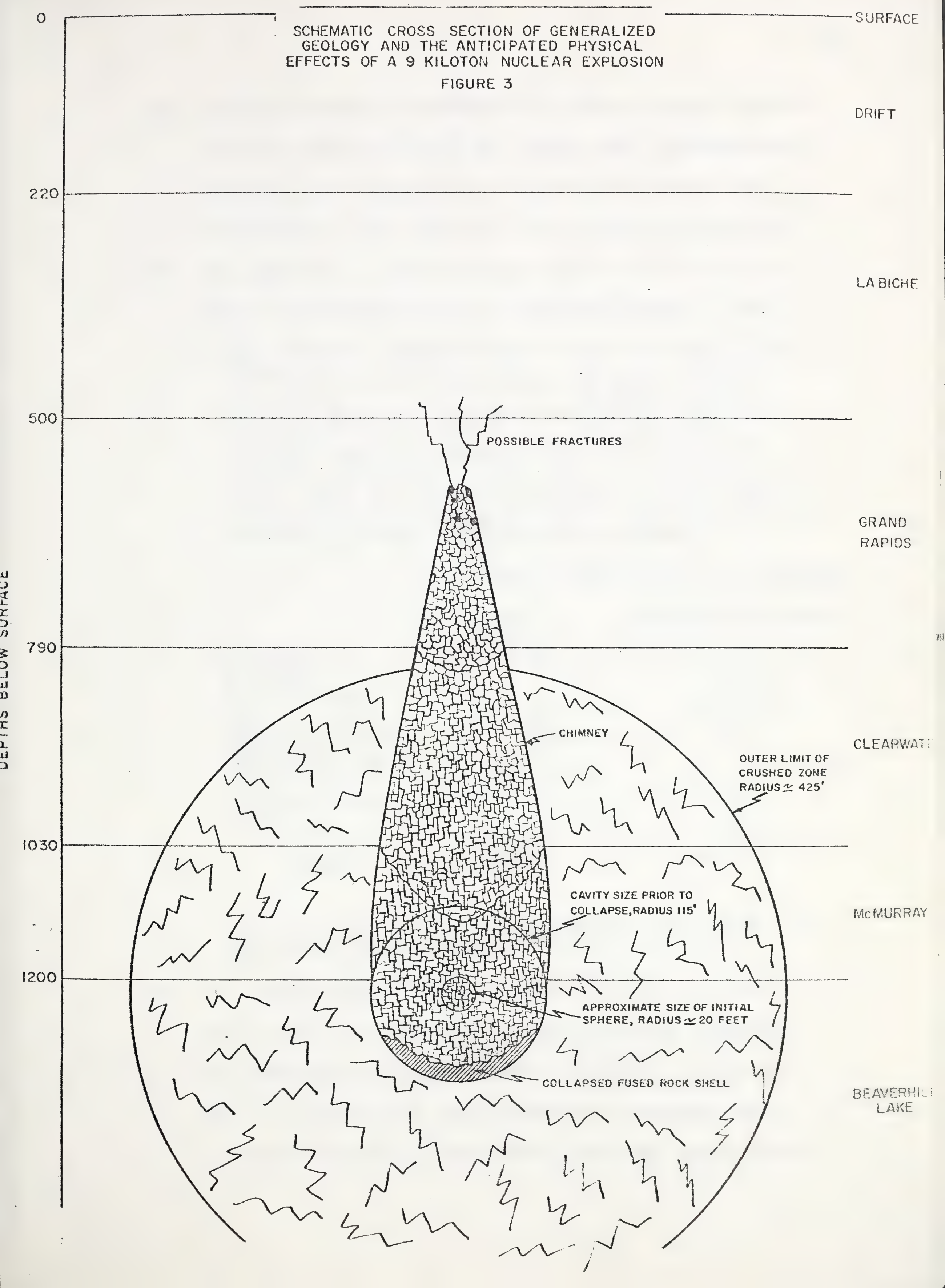
At the direction of the Alberta Technical Committee, extensive physical and chemical analyses[1.d][1.e] have been made by the Richfield Oil Corporation on samples of the rock formations found in the proposed test area. Check analyses[1.e][6] have been made by the University of Alberta and the Mines Branch of the Department of Mines and Technical Surveys in Ottawa and extensive data of the Research Council of Alberta have been employed. Study of these data has led to the conclusion that the physical properties of the rock in the various formations of the test area are similar to those of the volcanic tuff in which the underground nuclear explosions were made in Nevada. As a result, the Committee has relied directly on the results of the Nevada tests, rather than to attempt to modify them to conform to the rock properties of the test area. It is felt that this procedure provides a margin of safety in that the test area rock is of somewhat greater strength than Nevada tuff.

At the present time the design of a nuclear explosive is such that the lower limit of energy release cannot be guaranteed within close tolerances. However, the upper limit is known with reasonable certainty, since it depends on the total fissionable material in the device. Dr. G. W. Johnson, Associate Director, Lawrence Radiation Laboratory, who has been directly associated with the underground nuclear explosions in Nevada, has positively assured the Alberta Technical Committee that a nuclear explosive having a rated size of 9 kilotons would have a maximum yield of 9.5 kilotons.

Considerable theorectical and practical knowledge has been gained from the five underground tests[1.k] carried out in Nevada. Based on this knowledge and studies and calculations prepared by the Lawrence Radiation Laboratory[1.d][1.f][5], it is possible to predict the major effects of a 9 kiloton nuclear explosion. A schematic cross-section showing the general geology and the anticipated physical effects is presented in Figure 3.

A chronological sequence of the anticipated effects if a 9 (or 9.5) kiloton explosive were detonated 20 feet into the Beaverhill Lake formation at the proposed location follows.

(1) The detonation would involve the fission of the equivalent of approximately 1 pound of uranium 235, releasing 9 trillion calories of energy. About 50 per cent of this energy is deposited as heat at useful temperatures, some 40 per cent appears locally around the "useful heat" zone as low temperature heat, and the remainder is dissipated as long range seismic energy.



SCHEMATIC CROSS SECTION OF GENERALIZED GEOLOGY AND THE ANTICIPATED PHYSICAL EFFECTS OF A 9 KILOTON NUCLEAR EXPLOSION

FIGURE 3

(2) At the instant of detonation a vapor cavity about 8 feet in diameter would be formed with temperatures reaching several million degrees Centigrade and pressures of the order of 30 million atmospheres.

(3) In a period of less than one millisecond the rock would be melted out to a radius of about 20 feet.

The chemical composition of the Beaverhill Lake limestone in which it is proposed to detonate the explosive was determined by analyses of samples taken at five foot intervals from the Pony Creek No. 2 well[1.d]. The analyses indicate that the composition over a 40 foot interval (diameter of melting and vaporization zone) below the McMurray-Beaverhill Lake contact varies over the following ranges and would be expected to have the following average:

	Per Cent by Weight (air-dry basis)	
	Range	Estimated Average
Silica	1.5 - 23	13.5
Alumina	0.8 - 5.4	3.0
Ferric Oxide	0.4 - 1.5	1.0
Calcium Oxide	25 - 49	40.0
Magnesium Oxide	0.3 - 0.8	0.7
Potassium and Sodium Oxide	0.3 - 1.1	1.0
Carbon Dioxide	29 - 43	39.0
Other	1 - 2	1.8
Total	100	100.

The material in its natural state contains 6 - 7 per cent water by weight.

(4) In the immediate vicinity of the centre of the explosion, all chemical compounds would probably be reduced to stripped atomic nuclei. As the cavity expands and the temperature becomes lower condensation would take place from the vapor phase

on the surface of the molten layer. As the shock moves outward the melt-lined sphere of 20 foot radius would be expanded radially by extreme compression of the rock to a final spherical cavity having a radius of 115 feet.

Chemical reactions between the melted rock ingredients would lead to a mixture approximating the following composition:

	Per Cent by Weight
Dicalcium silicate	36 - 38
Calcium carbonate with traces of magnesium carbonate	28 - 30
Aluminum and iron oxides, carbonates and silicates	28 - 30
Other	2 - 4
Total	100

(5) Meanwhile the shock energy would be propagated outwards in all directions. Its two further major effects would be

(a) to cause crushing of the rock beyond the region of melting and to a radial distance of 400 to 450 feet, and

(b) to cause the collapse and complete sealing of the placement well due to the higher velocity of shock waves through the dense formations around the well than through the collapse chambers which would be provided in the well. (The collapse chambers would probably be air filled containers.)

(6) Beyond about 450 feet the shock energy would be dissipated and would result in low temperature heating of the formations.

(7) Shock waves would reach the surface of the earth in a fraction of a second. Directly above the explosion the effect of the shock waves would be apparent as a quite violent shaking of the surface causing soil or snow to be kicked up and loose rocks or other debis to be disturbed. (To the uninitiated these visible effects could give the appearance of a breakthrough). At distances of 1 to $1\frac{1}{2}$ miles the motion of the surface of the earth would be strong enough to violently rock an automobile. At 5 miles (the approximate distance to railroad) the surface effects would not be strong enough to damage any surface installations and at 15 miles the shock wave effects would only be felt by sensitive observers. A permanent upward displacement of the surface of the earth of a few inches might result over an area of a few acres directly above the point of detonation.

(8) After about one-tenth of a second the spherical cavity would be expanded to its maximum size, and would have a gaseous centre and a lining of molten rock about 3 inches thick. The gases at this time would be principally water vapor, carbon dioxide and those fission products which are gaseous under these conditions. The pressure in the centre of the cavity

is estimated to be less than the overburden pressure which is about 1,200 pounds per square inch and the temperature would be near that of the melting point of the complex carbonaceous mixture (1500°C - 2500°C).

(9) Associated with the detonation would be 1.3×10^{24} fissions yielding 2.6×10^{24} fission products distributed among some 37 nuclides in the double peaked mass-yield curve(5) familiar to nuclear scientists. One second after the detonation, some 40 per cent of the radioactivity would be in the gaseous core of the spherical cavity and the remaining 60 per cent would be in the molten shell.

(10) After a time ranging from a few seconds to a few minutes the cavity is expected to collapse from the weight of the then crushed overburden. Overlying material in the McMurray, Clearwater, and to some extent the Grand Rapids formations, would fall into the cavity causing a "chimney" to grow upwards. The original spherical cavity and the chimney would "fill" with the rock debris and would have a high porosity and permeability. The introduction of this debris and its associated oil and water to the high temperature cavity will result in a lowering of the temperature to an average value probably at or somewhat below the boiling point of water.

(11) Undoubtedly the heat of the explosion would cause the decomposition to carbon, hydrogen and hydro-

carbon gases of a part of the oil in the lower reaches of the McMurray formation immediately above the initial spherical cavity. Radially beyond the cavity the oil would be heated and would undergo thermal cracking to an extent varying inversely with its distance from the initial spherical cavity. After the cavity collapses the hydrogen and hydrocarbon gases would mix with the carbon dioxide and water vapor formed earlier. As the oil sand collapses into the cavity and temperature equilibrium is approached the oil is expected to become sufficiently fluid to drain downward to fill the pore spaces in the lower portions of the rubble zone. The gases first present in the pore spaces would be displaced to the chimney itself.

(12) The height to the top of the chimney is expected to be between 250 and 350 times the cube root of the energy released. For a 9 kiloton explosion this calculates to a height between 600 and 730 feet. (The United States Atomic Energy Commission "safe confinement depth"[1.k] of 450 times the root of the energy release suggests 930 feet to be a safe depth for a 9 kiloton explosion. In the proposed location at a depth of 1,220 feet there would be an additional 290 feet above that depth considered safe by the United States Atomic Energy Commission).

(13) Upon collapse of the cavity and during the subsequent formation of the chimney, the gases and radioactive compounds present in the gaseous phase would rapidly diffuse to fill the pore spaces throughout the enlarged cavity. As decay of the rare gas fission products to condensible form occurs, and as the temperature lowers, the previously volatile fission products would react with the surfaces of the rock debris. A small fraction of the radioactive products would continue to exist for long periods as rare gases.

(14) At a time approximately one minute after the explosion the total radioactivity would have declined to about 0.24 trillion curies -- about 1/36[1.d] of what it was at one second. About 43 per cent of this remaining radioactivity would be entrapped in the solidified shell fragments, some 47 per cent would be associated with the rock debris in the cavity and about 10 per cent would remain in the gas phase.

(15) The oil is not expected to be significantly contaminated with radioactive products from the fission because the radioactivity would be distributed among the shell fragments, the rock debris and the gas phase, and the solubility of the radioactive compounds in the oil should be small. However, it is possible that some of the mineral matter in the oil may be radioactive.

(16) Some bombardment of the oil by a small fraction of the neutrons from the fission reaction may take place during the earlier stages of the explosion, although it is expected that the neutrons will be harmlessly absorbed by intervening material. If the oil is so irradiated it becomes temporarily radioactive, but laboratory experiments[1.j] have indicated that no long-lived or dangerous nuclides are formed.

(17) One year after the explosion the total radioactivity would be expected to have decayed to 57,600[1.d] curies or 1/137,000,000 of what it was at one second.

(18) The permanency of the entrapment of radioactive products in the broken fragments of the shell would depend upon the solubility of the fragments in water. The solubility of these fragments varies over quite wide limits[1.d]. While some of the constituents are relatively insoluble, in general the shell which would be formed in the limestone medium must be assumed to be much less "insoluble" than that which entrapped a large fraction of the radioactive products in the Rainier test[5] in Nevada.

(19) Such radioactivity from the broken shell fragments as dissolves, together with that remaining in the gas phase in the chimney and possibly part of that deposited on the rock debris, would eventually find its way into underground waters. The Grand Rapids

formation is known to contain underground water and it is possible that active aquifers may also exist at the base of the McMurray and even in the Beaverhill Lake formation.

(20) The rate of movement of the water in the Grand Rapids aquifer(1.i) is not known with precision but a detailed study of all available data suggests rates of the order of 3 feet per year. The rate of movement of water in other aquifers, if present, is expected to be in the range of 0 to 3 feet per year.

(21) The radioactive products dissolved in the underground waters will tend to be removed by "ion exchange" with the mineral matter(1.d) through which the water passes, thus reducing the rate of migration of the radioactivity to a value considerably below that of the water. From a public safety point of view, only the movement of the biologically dangerous isotopes strontium-90 and cesium-137 into underground waters need be of concern.

Generally speaking the overall effect of the proposed explosion would be the creation of an underground debris filled chamber (cavity and chimney) which would contain all radioactivity and into which heated oil may be expected to flow. All radioactivity present is expected to be associated with rock debris, with fragments of solidified once-melted rock and with gas in the upper part of the chimney. Little radioactivity is expected in the oil. The leaching action of underground waters will cause the slow migration of radioactive particles laterally

away from the site, but it is expected that their radioactivity will have decayed to insignificant levels before they migrate far.

6. PUBLIC SAFETY ASPECTS OF THE TEST

The Committee has given a great deal of thought to the overall question of public safety and to the safety of the personnel who would be necessary at the site area. Indeed the bulk of its concern with respect to the chemical, physical and radioactive effects to be anticipated has related directly to safety.

The representative of the medical profession on the Committee has concerned himself with the assessment of the possible hazard to public health if appreciable quantities of radioactive materials were to be released to the atmosphere[e]. However, the Committee is in fact unanimously satisfied that the risk of any release of harmful radioactivity to the atmosphere is negligibly small. The Committee believe that the final design of the test can be such that the explosion would be completely and safely contained beneath the surface and that all radioactive products would be contained either in the fragments of the shell lining of the original spherical cavity or associated with mineral matter and slow moving underground waters.

Even assuming the worst case that the shell would not serve to permanently trap any of the radioactive products, the project would still be safe. Cesium-137 and strontium-90, the only biologically hazardous radioactive products produced in

---

(e) See Appendix 5, Some Aspects of Public Health and Safety by Dr. D. A. L. Dick, Member of the Alberta Technical Committee.

significant quantities, would be in solid form a few minutes after the detonation and they would either remain at depth and decay or, being soluble in water, be transported by moving subsurface waters.

The movement of those products taken into solution would be at a considerably lower rate than that of the water since they have a strong tendency to be transferred to earth minerals through which the water would be flowing. A study [1.i] of the ground water movement in the area, as discussed earlier, based on the present limited data (which would be further checked prior to the test) shows that the rate of water movement in the aquifers is about 3 feet per year. If these rates are confirmed prior to the test then it will be fair to say that radioactive products would be transported at depth at rates considerably less than 3 feet per year. As the half life of strontium-90 and cesium-137 is about 30 years, it can be seen that the radioactivity of these products would be down to negligible levels before they travel significant distances. Some data and theoretical observations with regard to contamination of ground waters have been published by Higgins [1.d].

The extent of the contamination of the oil would depend to some extent on the final positioning of the device. Little if any of the primary radioactivity should enter the oil phase because of its temporary (at least) entrapment in the cavity shell. Even if the cavity collapses much earlier than expected the radioactivity would be preferentially associated with mineral matter rather than the oil. Although the production

of oil containing small amounts of entrained radioactive mineral particles could be a problem it is not important to these considerations as at worst the production could be delayed pending decay to safe levels. Induced radioactivity is possible if the neutrons emitted from the fission reaction reach the oil but even this is doubtful. Irradiation tests[1.j] on samples of the oil have been made at very high neutron densities and these show that in a matter of about seven days the radiation decays to negligible quantities. As a precaution, however, it is contemplated that any oil produced would be carefully monitored for radioactivity and decontaminated.

The only other possible appearance of radioactive products at surface would be their recovery during post-shot drilling operations in the general cavity area. Post-shot drilling and tunnelling experience[1.k] at the Nevada testing grounds has shown that the amounts would be very small and that they could be easily handled. In this connection an experienced decontamination expert, as well as a qualified medical person, should be available at the test site from the time the nuclear device arrives until all hazardous operations are completed.

With regard to the possibility of an unscheduled explosion during the transportation to or the lowering of the explosive into the well, the Committee has been positively assured that a nuclear explosion or reaction cannot occur prior to the deliberate arming of the explosive. The worst that could happen in the event of an air crash or the like is that the fissionable material could be scattered over a small area but no fission

reaction could occur. It is proposed that the nuclear explosive be transported into Canada and to the general site area by the United States Atomic Energy Commission by well established means mutually acceptable to the Canadian and United States governments.

The assembly, arming, timing and firing of the explosive would be handled by a group of experts directed by or under contract to the United States Atomic Energy Commission. The standard precautions normally taken by these experienced agencies should be acceptable to the Alberta authorities with perhaps some minor modifications due to the slightly different conditions in this case. Standard precautions[1.h] require that all timing and signal circuiting and the like be checked by personnel designated by the United States Atomic Energy Commission and that at no time before zero hour is the explosive to be armed. Because of the difficulties that could be encountered in recovering the explosive from the placement well due to hole troubles, a dummy run using a dummy device perhaps slightly larger than the actual should be run into place in the well and as much of the timing and circuiting as is practical checked under these downhole conditions. These dummy runs should be continued until such time as a trouble free run is performed.

The hole should be stemmed using a combination of plugs and drilling fluid designed in such a manner that the hole would be collapsed as near to the subsurface shot point as possible. Some theoretical considerations in the stemming of a well have been submitted by Richfield Oil Corporation[1.g]. As there is always a remote chance that the nuclear explosive

may have to be recovered from the well before being armed, the stemming of the well should be so designed that this could reasonably be done. As an added precaution, Richfield Oil Corporation propose to install an adequate shut-off valve assembly on the placement hole casing at the surface.

Just prior to the arrival of the nuclear explosive in the area, a strict security program should be instituted. An area of about 600 square miles surrounding the placement well should be closed off to the public and the security program modified only as conditions permit after the explosion. Once the security program is in force, every person allowed within the area would be issued an identification card bearing his photograph and containing a film badge which would be read for radiation exposure at regular intervals.

Provision should be made for the availability of meterological advice so that the explosive may be fired under the most desirable wind conditions. An examination of the general area suggests that a wind from the south-west, or from the east would be most desirable.

As a further precautionary measure the Oil and Gas Conservation Board should consult with such public health authorities as the Department of Public Health of the Province of Alberta and the Faculty of Medicine at the University of Alberta to insure that the data proposed to be obtained before, during and after the test would permit the complete assessment of the biological consequences of the test. This might be arranged through Dr. D. A. L. Dick, member of the Committee.

All factors considered the Committee is convinced that with proper precautions there would be no hazard to public health from the detonation of the underground explosion as discussed.

7. PRE-SHOT DATA REQUIRED FOR ULTIMATE EVALUATION OF RESULTS

Considerable pre-shot data would be necessary to determine the final design of the test, to satisfy the conditions of the Approval and to serve as a basis for the later interpretation of the results. It would be necessary to obtain detailed information from wells at or very near the proposed placement well and at three or four equally spaced points 500 - 1,000 feet radially away.

At or very near the test hole itself a well should be continuously cored to a depth about 300 feet below the McMurray-Beaverhill Lake contact. The core should be sealed immediately upon recovery so that virgin condition measurements may be made of the rock and contained fluids. In addition electro-, micro- and temperature logs as well as a special high sensitivity radition log with carefully calibrated equipment should be obtained. Significant aquifers would be determined from an examination of the cores and logs and these aquifers should be individually sampled and production tested. The details of pressure and flow measurements which should be made are discussed later. It would be necessary to conduct appropriate chemical analyses of samples of the core, the McMurray Oil and the production samples from the aquifers. Certain physical and mechanical properties would have to be measured on samples of the core and the McMurray oil. For post-shot reference purposes the background radiation levels should be determined on samples of the formations, of McMurray oil, of underground

waters and of surface soils and the air.

To permit an accurate evaluation of the rate of flow in the aquifers, and later to serve as observation wells, three or four equally spaced wells should be drilled at 500 - 1,000 feet radius from the test well for each of the important aquifers. One set of these wells should be cored through the McMurray section and be electro- and temperature logged to 300 feet below the McMurray-Beaverhill Lake contact. The aquifers would be located by means of the logs and production water samples should be taken from each well. These water samples, together with samples of the McMurray oil, should be tested for background radiation and chemically analyzed.

The well at or very near the placement well and the three or four wells 500 - 1,000 feet away should permit a reliable determination of the rate of flow of water in each aquifer. This determination would involve a carefully planned program, including accurate measurement of the water level in each of the five wells before, during and after production tests.

To determine the extent of any permanent surface displacements a grid of accurately located bench marks should be required.

8. DATA REQUIRED DURING TEST

It is important that records of ground movement, both near and at a distance from the site should be made during and immediately after the explosion. Near the source, the precise speed with which the shock wave would move up to the earth's surface gives a measure of the actual energy release of the explosive used. The very near measurements would be made with detectors cemented at intervals into drill holes near the placement well, and with others on the surface directly above the explosive. Since the shock would arrive at these near points in a very small fraction of a second, specialized equipment for measuring small time intervals would be necessary. It is desirable that the observations would be available to Canadian scientists so that an independent estimate of the actual energy yield could be made.

It is the usual practice also, at the time of the test, to photograph the earth's surface at the site with a motion picture camera. The records obtained would give evidence of any break-through to the surface, and of the extent to which loose material might be thrown into the air by the shock wave.

Beyond the immediate area of the test, out to a radius of say 60 miles, is a region in which seismic measurements should be made for ground motion. Still further from the site, the ground motion could be detected only with sensitive seismographs. There is, however, considerable scientific value in ground motion recording, at distances up to several hundred or

1,000 miles, in order to increase the knowledge of major geological structure in western Canada. Hence the information obtained would be of long range economic importance as well as of purely scientific interest. Measurements would be made as a matter of routine at permanent seismological observatories, and also at temporary field locations. The latter would be provided by the Dominion Observatory, the University of Alberta and probably by a number of co-operating seismic parties such as the group from the International Geophysical Year Committee for Joint Seismic Experiment which obtained useful data from the Ripple Rock explosion. The only requirement at the site for this work would be the accurate timing of the instant of detonation. It would also be most useful if the Canadian Broadcasting Corporation would broadcast this event with the same service as performed at the time of the Ripple Rock operation, which gave valuable seismological information.

Some transmission of pressure from the explosion may be expected through the principal aquifer in the area, that of the Grand Rapids formation. It would be of value to determine the pressure fluctuations in observation wells for a short period following the shot. This could be done by continuous measurement and recording of liquid levels at each of the three or four observation wells located 500 - 1,000 feet from the shot point.

9. POST-SHOT DATA FOR ULTIMATE EVALUATION OF RESULTS

Subsequent to the explosion a careful program of testing, sampling and monitoring should be required to evaluate the results. A series of wells should be drilled to obtain most of the data.

The first post-shot evaluation well would be drilled some 500 - 700 feet from the placement well. The drilling procedures on this and subsequent wells should be such that they can be conducted under pressure at all times. The drilling fluid system should be completely enclosed. Pressures, temperatures and levels of radioactivity of the circulating drilling mud, rock cuttings and the like should be continuously monitored on remote gauges. If readings are not within safe handling limits the mud and any materials recovered from the well should not be exposed to the atmosphere. All evaluation wells would be cased and equipped with blow out prevention equipment[1.b]. It is not expected that any abnormal pressures or temperatures would be encountered at the time of drilling to the extent that difficulties would occur in the drilling or control of these wells. Once the drilling has entered the cavity area some radioactivity would probably appear in the drilling system. Experience[1.k] in Nevada has shown that the level of radioactivity would be low and primarily contained in the drill cuttings and core being recovered. This means that most of the radioactivity in the circulating fluids could be removed by passing the fluid through a desander. The disposal of the

radioactive rock cuttings and particles from the desander would probably be to some suitable subsurface horizon. This is currently the waste disposal practice at Chalk River, Ontario.

Precautions should be taken to continuously monitor any equipment being retrieved from the well bore. Any equipment that is radioactive could be readily decontaminated by washing with water. The wash water could be either decontaminated by filtering or disposed of to the subsurface.

Depending upon the observations made at the first well, a second well would likely be drilled about 300 feet from the placement well and the same procedures followed and precautions taken. After assessing the results of these wells a well may be drilled into the debris filled cavity after the radioactivity had decayed to a low level. This well would be completed in such a manner as to determine the success of the test for oil recovery purposes.

The following series of measurements and samples should be taken in most of the post-shot test holes:-

1. Conventional drill stem tests of the water bearing formations. Samples of the water should be tested for radioactivity and chemical properties and compared with pre-shot data.
2. Rock cuttings of all formations penetrated may be available in the returned drilling fluid and their radioactivity should be monitored. Samples of cuttings taken from regions where transient high temperatures would be expected should be tested

for physical and chemical alteration.

3. Core sampling, particularly in the crushed and high temperature zones, should be attempted to permit macroscopic tests for changes in physical properites such as density.
4. Rate of bit penetration and loss of drilling fluid returns should be observed since they would give useful data on induced fractures and crushing caused by the explosion. The extent of development of the chimney above the shot point would also be readily recognized by these observations.
5. Radiation intensity, temperature and electric logs should be taken of each hole, and by reference to pre-shot data, radioactivity and temperature profiles could be constructed.
6. Drill stem tests of the oil sand formation in the vicinity of the shot point would be expected to give recoveries of oil and gas and aid in the assessment of the feasibility of the process. Changes in the physical and chemical properties of the oil, and any induced or carried radioactive effects, as related to distance from the explosion would be of particular importance.

While the data obtained during the course of post-shot drilling would be of primary importance, certain long term

follow-up information would be necessary to relate temperature and intensities of radioactivity with time. Some of either the pre-shot or post-shot test wells should be cased and completed so that periodic measurements could be made of migration of radioactivity through ground water movement and of the long term radioactivity and heat transfer effects in the oil sands and adjacent formations.

No airborne or ground surface radioactivity is expected from the explosion. Notwithstanding this some monitoring should be carried out at the test site and at selected points within about a sixty mile radius.

10. RECOMMENDATIONS

The Committee has considered the overall proposal in much detail and has attempted to assess all possible effects. It believes that the proposed test could be carried out without danger to public health, plant and animal life or significant loss of natural resources. Moreover, the Committee believes that it is to the advantage of the Province of Alberta, being the owner of the oil resources in the McMurray area, that the test be carried out.

The Committee, therefore, recommends that the Lieutenant Governor in Council approve the project and that the necessary well licences and approvals be issued,all subject to the following terms and conditions and the conformity with them by Richfield Oil Corporation.

1. Prior to the import into Canada of the nuclear explosive, Richfield Oil Corporation shall obtain the necessary approvals from the Government of Canada for the import into Canada, the transport in Canada and the detonation in Canada of the nuclear explosive.
2. Prior to the import into Canada of the nuclear explosive, Richfield Oil Corporation shall obtain the co-operation of the Atomic Energy Commission of the United States for the conduct of the test.
3. Prior to the import into Canada of the nuclear explosive, Richfield Oil Corporation shall satisfy the Oil and Gas Conservation Board of Alberta with

the details of the organization and personnel arranged for the test. From the time the nuclear explosive is in Alberta all operations involving the explosive shall be under the "stop-go" control of a directorate of three persons representing the Oil and Gas Conservation Board of Alberta, the Atomic Energy Control Board of Canada and the Atomic Energy Commission of the United States and any one of these persons shall have the power to "veto" such operations or any part of them at any time.

4. The rated yield of the nuclear explosive shall not exceed 9 kilotons.

5. At the time of detonation, the explosive shall be positioned at a depth of 20 feet ± 2 feet below the McMurray-Beaverhill Lake contact (approximately 1,220 feet below the surface) in a hole drilled and cased for the purpose at a location within Legal Subdivision 10, Section 32, Township 79, Range 7, West of the 4th Meridian. This condition may be varied by the Oil and Gas Conservation Board after reviewing the information required under condition 8(a); provided, however, that the required depth below the surface shall not be less than 1,150 feet.

6. The drilling, casing cementing and completion of all wells and the stemming required at the wells shall conform to the specifications prescribed by the Oil and Gas Conservation Board.

7. Richfield Oil Corporation shall pay the costs of such safety and security measures as the Oil and Gas Conservation Board may require.

8. Prior to the placement and detonation of the explosive, Richfield Oil Corporation shall satisfy the Oil and Gas Conservation Board

   (a) that it has conformed with the detailed requirements of, and has submitted the data required in Schedule A to these conditions, and

   (b) that it has prepared itself for compliance with the detailed requirements of Schedules B and C to these conditions.

   Schedule A to these conditions shall stipulate the details of drilling required, samples to be taken, measurements to be made and tests to be conducted prior to the detonation of the nuclear explosive. Schedule B to these conditions shall stipulate the details of samples to be taken, measurements to be made and tests to be conducted immediately before, during and immediately after the detonation of the explosive. Schedule C to these conditions shall stipulate the details of drilling required, samples to be taken, measurements to be made and tests to be conducted after the detonation of the explosive.

9. Schedules A, B and C to these conditions shall be developed by the Oil and Gas Conservation Board having regard to the public health and safety

recommendations of Section 6 and to the technical and general safety provisions of Sections 7, 8 and 9 of this report.

10. Schedules A, B and C may be amended from time to time by the Oil and Gas Conservation Board if and when warranted in the interest of practical operation and safety.

Respectfully submitted,

G. W. Govier (Chairman)

D. A. L. Dick

D. R. Craig (Secretary)

G. Garland

C. P. Gravenor

H. E. Gunning

A. F. Manyluk

A. R. Patrick

H. H. Somerville

Date: ______________________

R E F E R E N C E S

1. "Project Oilsand" report by Richfield Oil Corporation, July, 1959, containing the following:

(a) General Report

(b) Appendix A including

(i) Operations plan.
(ii) Copy of Application to the Oil and Gas Conservation Board of Alberta for Licence to Drill New Well.
(iii) Proposed Blowout Prevention Equipment for Post-Shot Drilling.

(c) Exhibit I, R. I. Smith, "Geologic Report", Richfield Oil Corporation, June 9, 1959.

(d) Exhibit II, Compilation of Chemical Analyses Reports.

(e) Exhibit III, Compilation of Physical Analyses Reports.

(f) Exhibit IV, J. Nuckolls and M. Nordyke, "Prediction of Effect of 9KT Explosion by Nuckolls Method and Extrapolation to Other Yields", Lawrence Radiation Laboratory, University of California, Livermore, California.

(g) Exhibit V, G. T. Pelsor, "Stemming Prediction Report", Lawrence Radiation Laboratory, University of California, Livermore, California.

(h) Exhibit VI, "Safety Measures, Field Preparation and Detonation of Nuclear Explosive", compiled by the Staff of the University of California, Lawrence Radiation Laboratory, Livermore, California.

(i) Exhibit VII, "Hydrodynamic Analysis Report, Grand Rapids Formation, McMurray Area, Alberta, Canada, Petroleum Research Corporation, Denver, Colorado, March 31, 1959".

(j) Exhibit VIII, R. P. Taylor, "Hydrocarbon Study Report", Richfield Oil Corporation, Research and Development, Organ Research Division, May, 1959.

(k) Exhibit IX, G. W. Johnson and C. E. Violet, "Phenomenology of Contained Nuclear Explosions", Lawrence Radiation Laboratory, University of California, Livermore, California, UCRL - 5124 Rev. 1, December, 1958.

2. S. H. Ward and K. A. Clark, "Determination of the Viscosities and Specific Gravities of the Oils in Samples of Athabasca Bituminous Sand", Research Council of Alberta, Report No. 57, University of Alberta, Edmonton, Alberta, March, 1950.

3. "Lithologic Log of the well Richfield Pony Creek 2, located in Lsd. 9 of 1-80-8 W4th Mer.", Research Council of Alberta, Edmonton, Alberta, May, 1959.

4. G. C. Kennedy* and G. H. Higgins, "Temperatures and Pressures Associated with the Cavity Produced by the Rainier Event", University of California, Radiation Laboratory, Livermore, California, UCRL 5281, July, 1958.

5. R. E. Batzel, "Radioactivity Associated with Underground Nuclear Explosions", University of California, Lawrence Radiation Laboratory, Livermore, California, UCRL 5623, June, 1959.

6. "Report of Chemical Analyses", July 21, 1959, Mines Branch, Department of Mines and Technical Surveys, Government of Canada, Ottawa.

A copy of the listed references are available for inspection at the Department of Mines and Minerals office, Natural Resources Building, Edmonton, Alberta, and the Oil and Gas Conservation Board office, 603 - 6th Avenue S.W., Calgary, Alberta.

* Institute of Geophysics, U.C.L.A.

APPENDIX I.

OIL AND GAS CONSERVATION BOARD

PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.________________

I. N. McKINNON
CHAIRMAN

D. P. GOODALL, P. ENG.,
DEPUTY CHAIRMAN

G. W. GOVIER, P. ENG.,
BOARD MEMBER

VERNON MILLARD,
SECRETARY TO THE BOARD

603 - 6TH AVENUE S.W.

CALGARY ALBERTA

July 22, 1958.

The Honourable E. C. Manning,
Premier of Alberta,
Legislative Building,
Edmonton, Alberta.

Dear Mr. Manning:

I believe Mr. Somerville has already told you something of the proposal of Richfield Oil Corporation for a pilot test of the possibilities of recovering oil from the oil sands area with the aid of an underground nuclear detonation. Following their meeting with Mr. Somerville, and I believe at his suggestion, Mr. Stewart and others of Richfield Oil Corporation visited me in Edmonton and outlined the general technical features of the proposal. At this time, understanding that Mr. Somerville's reaction had been favourable, I told the party that the Board would be prepared to recommend the issuance of the necessary well licences and to support the project assuming that it received the necessary support from the appropriate Federal Government agencies and from any Provincial departments which might be involved. Dr. Natland of the Los Angeles office of Richfield Oil Corporation agreed to submit to the Board a more detailed, but still preliminary, description of the project. He also indicated that the Richfield party would call upon Dr. Convey, Director of the Mines Branch and other officers of the Federal Government in Ottawa.

On July 4, Mr. Stewart advised me that the party had visited with Dr. Convey, Mr. Ignatieff, Director of the Fuels Division of the Mines Branch; Mr. Watson, Secretary of Atomic Energy of Canada Limited and Mr. Longair of the Defence Research Board. My understanding is that the proposal met with the interest and general approval of these Federal Government officers. Richfield Oil Corporation, however, was advised that specific approval of several administrative branches of the Government would be required before the atomic device could be imported into Canada from the United States and before the tests could be carried out. Dr. Convey also requested that

Richfield Oil Corporation submit a technical report outlining the project to him.

On July 16, I met again with Dr. Natland, Mr. Stewart and others of the Richfield party to receive the technical report which they had promised. Mr. Craig, the Reservoir Engineer, Mr. Manyluk, Development Engineer and Mr. Pow, Chief Geologist for the Board were present. Unfortunately, both Mr. McKinnon and Mr. Goodall were away. At this meeting the preliminary technical report was reviewed and I reaffirmed that the Board would support the project subject only to the consent and approval of other Provincial and the appropriate Federal agencies. Richfield Oil Corporation has proposed to Dr. Convey that a meeting between the appropriate Federal and Provincial authorities be called, presumably by Dr. Convey, at the appropriate time for a detailed review of the plans. I understand that this meeting will be some time after August 14 which is the date when Richfield expect to deliver the technical report to Dr. Convey. Richfield Oil Corporation have asked that their proposal be treated confidential for the time being.

I believe that it would be desirable if the official attitude of the Province of Alberta could be pretty well defined at least by the end of August. It occurs to me that in addition to the Department of Mines and Minerals, the Department of Lands and Forests, the Department of Public Health and the Water Resources Branch of the Department of Agriculture might have an interest in the project. Also I believe it quite likely that the Research Council of Alberta could be of assistance in the consideration of certain aspects of the proposal. If you approve, this Board and Mr. Somerville could take the initiative here in the Province and call a meeting of representatives of the various Government Departments and the Research Council. After such a meeting we could propose for your approval the terms and conditions under which we believe the project could be safely approved.

Perhaps you would let us know if you think this procedure satisfactory.

Yours very truly,

G. W. Govier,
Board Member.

GWG/ce

cc - H. H. Somerville

OIL AND GAS CONSERVATION BOARD

PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.________________

I. N. McKINNON
CHAIRMAN

D. P. GOODALL, P. ENG.,
DEPUTY CHAIRMAN

G. W. GOVIER, P. ENG.,
BOARD MEMBER

VERNON MILLARD,
SECRETARY TO THE BOARD

603 - 6TH AVENUE S.W.

CALGARY, ALBERTA

October 22, 1958.

The Honourable E. C. Manning,
Minister of Mines and Minerals,
Natural Resources Building,
Edmonton, Alberta.

Dear Mr. Manning:

Re: Richfield Oil Corporation
Proposal for Oil Sands Development

You will recall my letter of July 22nd, 1958 and discussions which you had with Mr. Somerville concerning the proposal of Richfield Oil Corporation for a pilot test of the possibilities of recovering oil from the Athabasca Oil Sands with the aid of an underground nuclear detonation.

In accordance with the procedure suggested in my letter of July 22nd, which you verbally approved, Mr. Somerville and I met in his office with representatives of the provincial government departments of Agriculture, Economic Affairs, Health, Highways, Lands and Forests, Municipal Affairs and Public Welfare. In addition, representatives of the Research Council of Alberta were present and Messrs. Somerville and Corbet represented the Department of Mines and Minerals and I represented the Conservation Board. A list of the persons at the meeting is attached.

Mr. Somerville opened the meeting by pointing out that the area within which Richfield proposed to conduct the pilot test is beyond the bituminous sands permit area and under the jurisdiction of The Oil and Gas Conservation Act. Following this the test proposed by Richfield was described in some detail for the benefit of those who were not familiar with it. I informed the group that the technical staff of the Board had given careful consideration to the proposal and had come to the conclusion that a license could be issued for the drilling of the test well and approval could be given to the pilot program provided that there were adequate assurances concerning a number of potential hazards. The potential hazards were

then reviewed and members of the group were asked for their comments. The representatives of each of the departments made observations and comments on the procedure and the hazards against which precautions should be taken. The consensus of the group was that there was no reason not to approve the pilot test provided that the Conservation Board, after receiving the advice of the joint technical committee, was completely satisfied that the fullest possible precautions would be taken

1. to insure that there would be no surface breakthrough or fissuring resulting from the detonation,

2. to insure that the radioactive products of the fission reaction were effectively confined in an insoluble siliceous slag as had been the case in a test conducted by the United States Atomic Energy Commission in Nevada on September 19, 1957,

3. to insure that there would be no radioactive contamination of the oil in the oil sands or of any gas produced therefrom, and

4. to insure that there would be no radioactive contamination of the waters contained in the Grand Rapids Sand some 250 feet above the McMurray Sand or of the waters contained in the Devonian formation underlying the McMurray Sand.

In addition, the group were agreed that the well completion program should be most carefully reviewed by the Board and that the program proposed by Richfield for the collecting of technical data should be carefully studied by a joint technical committee to the end that Richfield should be required to obtain and report to the Board all desirable technical data to permit a complete evaluation of all aspects of the test. Mr. Martin of the Department of Economic Affairs stressed the importance of co-ordinated, carefullest thoughtout possibilities in the interest of avoiding public rumors and alarm based upon ignorance.

Richfield has submitted a technical report on the proposal to Dr. John Convey, Director of the Mines Branch, Department of Mines and Technical Surveys, Ottawa. Dr. Convey, representatives of Richfield and I agreed that it would be advisable to hold a meeting in Calgary with representatives of

The Honourable E. C. Manning October 22, 1958.

Richfield, the United States Atomic Energy Commission, Atomic Energy of Canada Limited, the Department of Mines and Technical Surveys (Ottawa) and the Conservation Board to further review the proposal and, in particular, to consider from a technical point of view the details of the precautions which should be taken. It is Richfield's view that technical representatives of the above mentioned bodies would form a joint technical committee for the project. October 29th has been set as a tentative date for this meeting although it is possible that it may be delayed a week or two. I believe that it would be desirable if the Conservation Board could indicate with some certainty at the meeting of the joint technical committee whether or not the pilot tests would be given approval of all necessary Alberta authorities provided that the Board was completely satisfied with the precautions to be taken. This appears to reduce to whether or not the Minister of Mines and Minerals on the recommendation of the Board would issue the necessary licence or licences.

I would appreciate it if you would let the Board know whether you would approve the issuance of such licences provided they were recommended by the Board. It seems to the Board and to Mr. Somerville that provided the proper precautions are taken (and these must be assessed by the joint technical committee) there is nothing to be lost and much to be gained from the proposed test.

Yours sincerely,

G. W. Govier,
Board Member.

GWG/pd
attach.

cc - Mr. H. H. Somerville

ATTENDANCE AT MEETING
October 9th, 1958

AGRICULTURE	-	R. M. Putnam
	-	Dr. E. E. Ballantyne
ECONOMIC AFFAIRS	-	H. Martin
	-	R. D. McLean
	-	E. S. J. Bryant
HEALTH	-	Dr. A. Somerville
	-	H. L. Hogge
HIGHWAYS	-	W. E. Curtis
	-	V. E. McCune
	-	J. P. Church
LANDS AND FORESTS	-	C. B. Kenway
MUNICIPAL AFFAIRS	-	A. W. Morrison
PUBLIC WELFARE	-	W. A. R. Rees
RESEARCH COUNCIL	-	Dr. C. P. Gravenor
	-	Dr. G. W. Hodgson
OIL AND GAS CONSERVATION BOARD	-	Dr. G. W. Govier
MINES AND MINERALS	-	H. H. Somerville
	-	J. B. Corbet

APPENDIX 3.

OPERATION OILSAND
PRE-APPROVAL REQUIREMENTS

INTRODUCTION:

It is contemplated that Richfield et al will be required to satisfy Canadian Federal and Provincial authorities at each of four distinct stages with respect to technical, safety and related matters. These stages are:

1. Pre-Approval.
2. Pre-shot.
3. Shot.
4. Post-shot.

Through meetings and reports from LRL and Richfield, the Canadian authorities now have a good general understanding of the proposal. A considerable amount of technical detail has also been made available. It seems desirable at this time, following discussions at Yucca Flats and San Francisco, to set out the additional information required by the National and the Alberta Technical Committee before Canadian approvals can be further considered. This document summarizes the additional Pre-Approval Requirements. It does not deal with Pre-shot, Shot or Post-shot requirements, all of which remain to be developed and probably can best be developed concurrently with the terms and conditions which would be attached to the Alberta approval.

ADDITIONAL REQUIREMENTS:

1. Application and Revised Project Description. Richfield et al should submit a formal application to the Oil and Gas Conservation Act* (with copies to J. Convey), for licences to drill the proposed wells. The applications should conform with the statutory requirements and should be supported by:

   (a) Full details of the drilling and completion program proposed at the wells - anticipated by June 1, 1959.

   (b) A brief and specific outline of the program of operations proposed at the wells - i.e. of the nuclear test - anticipated by June 1, 1959.

2. Further scientific and technical data. The following additional data are required.

* Typographical error - should read "Board".

. . . . . cont. 2

(a) Chemical analyses as indicated on Schedule A.
(b) Physical analyses as indicated on Schedule B.
(c) Prediction of effect of 9KT explosions by Nuckolls method, interpretation to other yields - LRL.
(d) Calculations to confirm the adequacy of the stemming proposed - LRL
(e) An outline of the arming procedure for the nuclear device and a discussion of the safety measures which would be taken to prevent an unscheduled explosion.
(f) An analysis of the chemical effects anticipated from an explosion in the Waterways Limestone - LRL, R.

NATIONAL TECHNICAL COMMITTEE (NTC)

John Convey, Chairman.

ALBERTA TECHNICAL COMMITTEE (ATC)

G. W. Govier, Chairman.

May 21, 1959.
Amended following meeting
of May 15, 1959, San Francisco.

(See also attached letters of Dr. G. W. Govier, dated May 22, 1959, and June 19, 1959, to Dr. J. Convey and Dr. G. W. Johnson, respectively).

SCHEDULE A
CHEMICAL ANALYSES REQUIREMENTS -

Material	Number of Samples (a)	Analyses (b)	Analyses by and Coverage
Grand Rapids Sandstone	6	Fusion	R (100%), RCA (10%) MB (20%)
Clearwater Shale	6	Spectrographic or Radioactivation	R (100%), RCA (10%) MB (20%)
McMurray Oil Sand	15	Mineralogical (c)	R (100%), RCA (10%) MB (20%)
Waterways Limestone	60	Cs, Sr Distribution coefficients (c)	LRL (100%), AECL(?%) UA (?%)
Rainier Tuff	5		

R - Commercial Laboratory approved by NTC and ATC and engaged by Richfield et al.
RCA - Research Council of Alberta.
MB - Mines Branch, Dept. of Mines & Technical Surveys, Ottawa.
AECL - Atomic Energy of Canada, Ltd.
UA - University of Alberta.
NTC - National Technical Committee.
ATC - Alberta Technical Committee.

(a) With the exception of the Rainier Tuff, samples have been collected and are in possession of RCA and will be distributed by RCA; Rainier Tuff samples to be distributed by Richfield or LRL.
(b) Details to be submitted by J. Convey and G. W. Govier.
(c) Only 10 samples of Waterways Limestone, indicated number of others.

PHYSICAL ANALYSES REQUIREMENTS

Material	Number of Samples	Analyses (b)	Analyses by and Coverage
Grand Rapids Sandstone	3	Density (dry, wet)	R (100%), UA or RCA (33%)
Clearwater Shale	3	Porosity	R (100%), UA or RCA (33%)
McMurray Sand	3	Permeability	R (100%), UA or RCA (33%)
		Specific heat (dry, wet)	R (100%), MB (33%)
Waterways Limestone	3	Comp. Strength (dry, wet)	R (100%), MB (33%)
Rainier Tuff	3	Thermal cond. (dry, wet) Equation of state (a)	R (100%), MB (33%) LRL (100%)

R - Commercial laboratory approved by ATC and engaged by Richfield et al.

UA - University of Alberta.

MB - Mines Branch, Dept. Mines and Tech. Surveys, Ottawa.

(a) On McMurray Oil Sand, Waterways Limestone and Rainier Tuff for certain, other formations if convenient.

(b) Details to be submitted by J. Convey and G. W. Govier.

OIL AND GAS CONSERVATION BOARD

PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.________________

I. N. McKINNON
CHAIRMAN

D. P. GOODALL, P. ENG.,
DEPUTY CHAIRMAN

G. W. GOVIER, P. ENG.,
BOARD MEMBER

VERNON MILLARD,
SECRETARY TO THE BOARD

603 - 6TH AVENUE S.W.

CALGARY, ALBERTA

May 22, 1959

Dr. J. Convey,
Director of the Mines Branch,
Department of Mines and Technical Survey,
OTTAWA, Ontario.

Re: Operation Oilsand
Pre-Approval Requirements

Dear John,

I have just finished a discussion with Dr. Gravenor of the Research Council of Alberta and Dr. Gunning of the Department of Chemistry concerning the details of the analyses which our two Committees were calling for under schedules A and B of our statement of May 15. Following are the details which the Alberta Technical Committee would wish to see attached to these analyses:

Chemical Analyses:

1. The fusion analyses required of all samples are the standard chemical analyses made on samples fused with solium carbonate and put into solution. The constituents for which determination should be made are the following -

   SiO_2 Al_2O_3 Fe_2O_3 (total iron) Na_2O

   K_2O CaO MgO P_2O_5

   MnO_2 absorbed and combined water

   loss on ignition CO_2 and sulphur.

2. The spectrographic or radioactivation analyses desired are for trace elements only. Results should be given for vanadium, titanium, nickel, copper, etc.

Dr. J. Convey,
Ottawa.

May 22, 1959.

3. The mineralogical analyses desired would include a quantitative separation of the clay constituents (mechanical analysis) and a complete mineralogical identification of the constituents.

4. The cesium and strontium distribution coefficients may be determined with distilled water although the Committee is somewhat concerned about the possible effect of dissolved solids and especially bicarbonate on the distribution coefficients. Any information to indicate the order of magnitude of this effect would be appreciated.

Physical Analyses

The physical analyses need little further elaboration except perhaps in the case of permeability. It is the intention of the Alberta Technical Committee that the air permeability be determined on oil free samples.

I would appreciate it if you would give consideration to these further details and advise me of any additions or alterations which you would like to see made. When I hear from you I will consolidate our ideas and distribute the material to all of the interested persons.

Yours sincerely,

G. W. Govier, Chairman,
Alberta Technical Committee.

GWG/is

cc - Dr. M. L. Natland
Richfield Oil Corporation.

Dr. G. W. Johnson,
Lawrence Radiation Laboratory.

OIL AND GAS CONSERVATION BOARD
PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.

I. N. MCKINNON
CHAIRMAN
D. P. GOODALL, P. ENG.,
DEPUTY CHAIRMAN
G. W. GOVIER, P. ENG.,
BOARD MEMBER
VERNON MILLARD,
SECRETARY TO THE BOARD

603 - 6TH AVENUE S.W.
CALGARY, ALBERTA

June 19, 1959.

Dr. G. W. Johnson,
Associate Director,
Lawrence Radiation Laboratory,
P.O. Box 808,
Livermore, California.

Dear Dr. Johnson:

At a recent meeting of the Alberta Technical Committee the Committee reviewed and approved the Pre-Approval Requirements which were drawn up and amended following our meeting in San Francisco May 15, 1959. One matter, however, on which the Committee was not entirely satisfied was its present knowledge concerning the distribution and amount of radioactivity which could be anticipated from the explosion. The Committee appreciates that there would be some discussion of this in Item 2F of the Pre-Approval Requirements but is not certain how extensive the discussion would be.

I wish, therefore, on behalf of the Alberta Technical Committee to request that you add a new Item 2G to the Pre-Approval Requirements as follows:

2G A discussion, as nearly quantitative as possible of the origin, type, distribution, amount and life of the primary and secondary radioactivity anticipated from an explosion in the waterways limestone - LRL, R.

For the benefit of those Committee Members who do not have too strong a background in Nuclear Physics and Radio Chemistry I would suggest that the discussion start from "grass roots" and develop the material in logical easy steps.

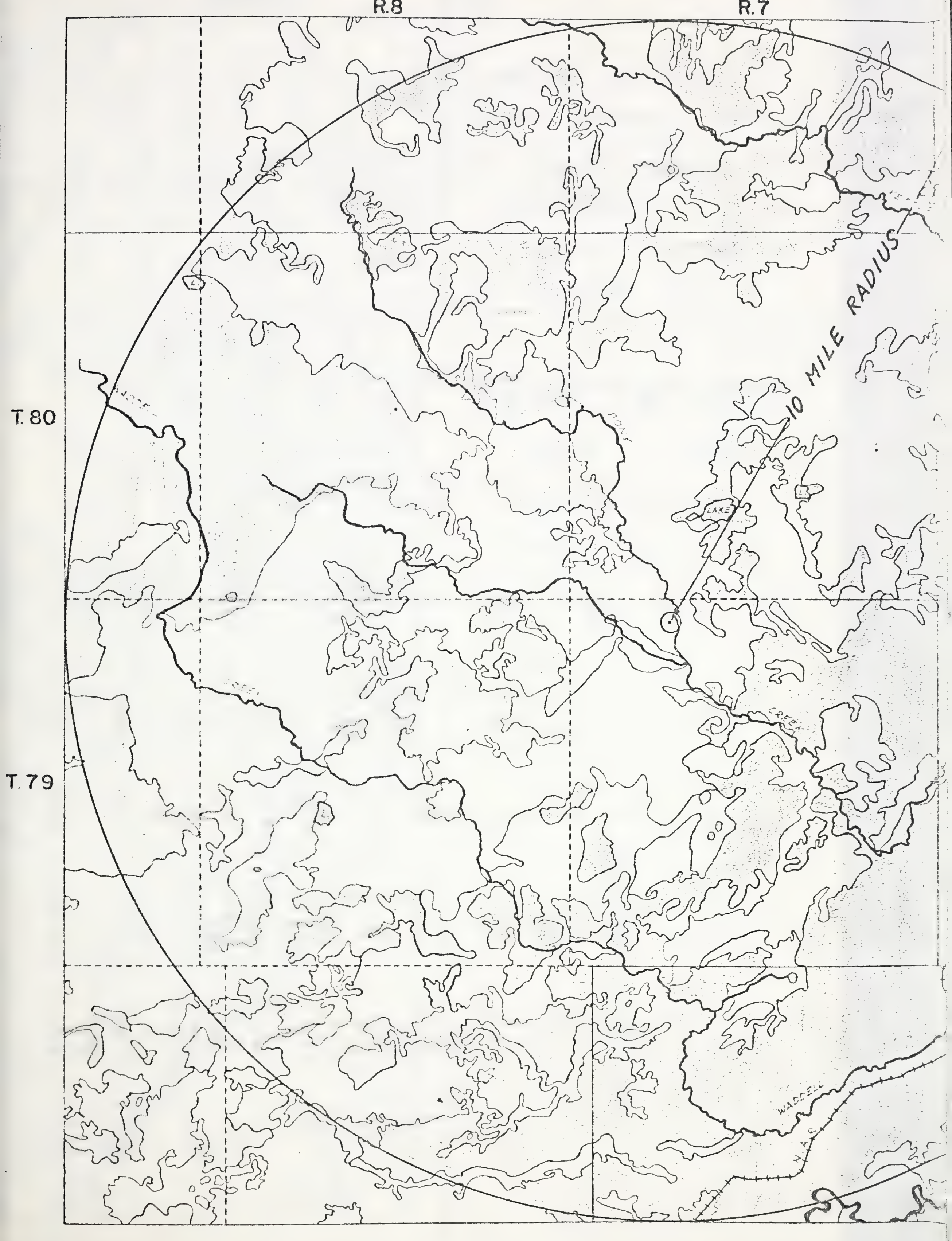
Personal regards.

Yours sincerely,

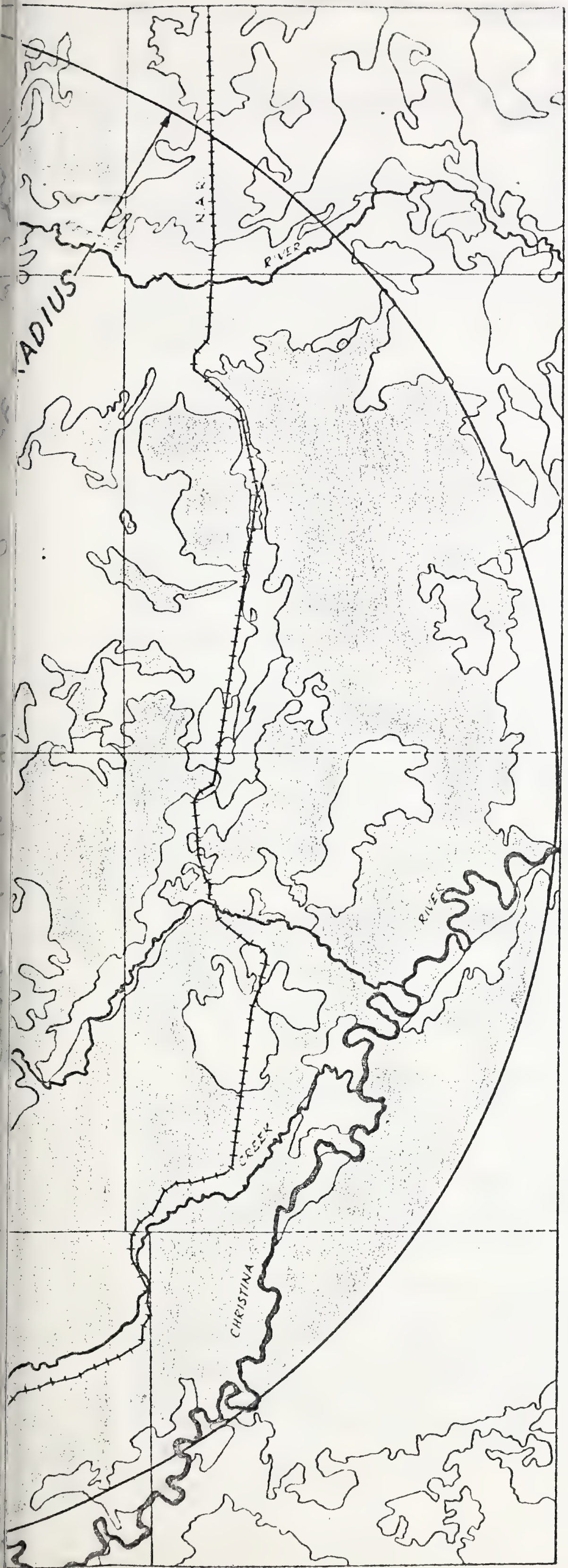
G. W. Govier, Chairman,
Alberta Technical Committee.

GWG/is

cc - Dr. M. L. Natland
Dr. J. Convey
Mr. S. Stewart
Mr. D. R. Craig



R.8
R.7
T. 80
T. 79
10 MILE RADIUS
LAKE
CREEK
WADDELL



PROVINCE OF ALBERTA

ALBERTA TECHNICAL COMMITTEE

PROJECT OILSAND

APPENDIX 4

AREA OF PROPOSED NUCLEAR TEST

VEGETATION

TREES

BRUSHLAND

OPEN LAND

N

AUGUST, 1959

APPENDIX 5

SOME ASPECTS OF PUBLIC HEALTH AND SAFETY

The problem of public safety has been dealt with in detail in Chapter 6 of the report of the Alberta Technical Committee. From the evidence supplied to us by the Radiation Laboratory of the University of California and Richfield Oil Corporation it would seem that the setting off of a nuclear device beneath the Oil Sands in Northern Alberta should pose little or no hazard to health or safety.

We have been assured that such a detonation and its radioactive contaminant products would be successfully contained far below the ground surface level. To ensure a safety factor, a level for detonation has been chosen which will allow quite a margin for error. We have also been assured that there is very little likelihood of radioactive gases or solids fissuring to the surface and causing contamination. If surface contamination were a possibility this would cause concern as it would be a danger to vegetable and consequently animal life in that locality. This possibility is most unlikely.

We have given the subject of ground water contamination considerable thought and again the evidence supplied would seem to indicate that most of the radioactive products will be trapped in the vicinity of the explosion and fixed to rocks and soils by means of ionic exchange and adsorption. The question of ground water movement still required some study but the evidence to date would seem to point to the fact that contamination of nearby streams and rivers is not to be expected.

When assessing the problem of safety we have also considered the possibility of an accidental explosion taking place either during transportation of the device to the site in question, or at the actual site. We are again satisfied that this is a most unlikely event.

From geological studies and knowing the amount of shock that will be transmitted to the surrounding area it is certain that a certain amount of earth tremor will take place at the time of the explosion. Precautions are being taken to evacuate all inhabitants and it is most unlikely that any accident could happen in this regard. It is not anticipated that damage will occur to buildings or the nearby railway.

It is understood by the writer that should the Alberta Technical Committee report be approved and permission given to Richfield for the test, there would be further consultations with medical personnel to insure that pre and post shot data proposed to be taken would be adequate to permit a thorough evaluation of the results from a biological point of view.

The object of this Appendix is to bring to the attention of lay readers some of the hazards of strontium and cesium contamination of the atmosphere and earth surface. This hazard is not thought to be likely in the test but it is felt from the point of view of general education that the biology and metabolism of cesium and strontium should be discussed.

BIOLOGICAL EFFECTS OF IONIZING RADIATION

We can definitely say that all evidence to date points to the fact that additional radiation to human life above background level is probably harmful, but just how far one can go above this background level and still be safe is impossible to say in the light of our present knowledge.

Ionizing radiation can cause shortening of life span and premature aging, it can induce cancer, and it can give rise to severe recessive genetic defects such as semi-fertility and physical and mental handicap and abnormalities. These may range from mild defects compatible with life to the most gross making life completely impossible. Transmitted and therefore genetic defects result from gonadal irradiation which produces recessive gene mutations. Nearly all such mutations are detrimental to the race, and the chance of any gene mutation producing a welcome beneficial mutation is incredibly small. We believe that gonadal irradiation produces changes which are irreversible and the total dose is additive and cumulative.

Somatic irradiation means irradiation to the individual and about this quite a lot is known at the present time. We know, for example, that certain elements such as calcium, strontium and radium are bone-seekers and there are authentic and well documented cases of bone sarcoma arising after radiation but with a latent period of some 10 to 25 years between the ingestion of the radium and the development of sarcoma. The induction of leukemia is also a major hazard.

Ionizing radiation became available in 1895 but for many years this tool was used only in diagnostic and therapeutic radiology and, of course, was therefore limited to a selected and relatively small segment of the population. Only since 1945 has the use of atomic energy become more widespread and we can only guess what may happen if large numbers of the population are exposed. Not enough time has yet elapsed for experience to accumulate in this regard.

Sr^{90} AND BONE-SEEKING ISOTOPES

The isotope of most concern is the bone seeker Strontium-90. Already the present level of strontium contamination from atomic bomb tests is a cause of some concern to responsible

people. All the strontium so far liberated has not yet come to earth and if weapon testing and the peaceful uses of atomic energy continue with this fact unheeded, a safe level may be exceeded which in the present light of our knowledge we can do very little about.

Physically strontium has a half-life; that is, it decays to half-strength in a period of some 28 years and decays a further 50% of its activity in the next 28 years and so on. In a human body it also has a biological half-life which is estimated at $7\frac{1}{2}$ years, but of course if ingestion continues this fact becomes somewhat meaningless as equilibrium levels must be reached. In fission bombs it is regrettable that the yield of Sr^{90} and Cs^{137} is so high; something like 1 in every 20 fissions (5%) yields an isotope of strontium.

At this point it should be clearly understood that the dosage received to the gonads is additive and produces recessive genetic mutations, which only become evident if offspring are produced. Somatic irradiation affects the person as a whole and results in damage which is often irreparable in a true sense, though a measure of recovery does occur. Once a certain integral dose has been received by a person in question the dose cannot be recalled, and many years may be required before its ultimate effect will be known; e.g. miners in Czechoslovakia and Germany who were subjected to radon gases developed lung cancer in an extremely high percentage of cases after a period of 15 to 25 years.

Bearing in mind that atomic energy has only been in use these last 15 or so years in any amount, it behoves us all therefore to see that as little radioactivity is released into the air, the soil, the superficial and deep waters of the earth, because only by doing this can genetic and somatic hazards to the world's population be reduced significantly for future generations.

Some day it will be possible to control fusion reactions and produce the same sort of effects as are suggested by fission devices for deep mining, the possibility of excavating and civil engineering. It is required that low fission to fusion ratio be realized and the reaction controlled before atomic energy can take major steps forward to useful purposes without too much radioactive contamination being a by-product as it is today.

As far as can be judged and especially if ionic exchange experiments are correct, the use of underground blasts for peaceful and commercial purposes seems to be the least dangerous form at the present time.

PERMISSIBLE LEVELS LAID DOWN BY INTERNATIONAL AGREEMENT

What constitutes a safe level of radiation is not yet known, either for the general population or for workers exposed by reason of their occupation, e.g. workers in radiology. It is significant that the suggested figures as laid down by protection committees have progressively been reduced over the past three decades.

PHYSIOLOGY OF Sr^{90} AND Cs^{137}

These isotopes as outlined are produced as a product of fission. Their local containment at the site of explosion is therefore of the utmost importance. Sr^{90} is by far the more important and has been the major contaminant from nuclear explosions. When it settles on the surface and subsurface of variable soils it is actively concentrated by plant life and vegetation. Very little leaching occurs by rain water and plants take this isotope up competitively with soluble calcium. So far the attempts by agriculturalists to minimize this uptake have been of little practical help.

Animals which ingest the contaminated vegetation are in turn eaten by human beings and dairy products are widely distributed. Strontium behaving chemically like calcium will concentrate in dairy products and it is a known fact that at the present time there has been some increase of contamination in powdered milk samples taken across various countries of the world.

Strontium contamination but to a lesser extent occurs in wheat and other crops grown on affected soil.

This hazard, of course, should not pertain in Project Oilsand providing no distribution by wind or soil occurs of the radioactive gases that might leak to the surface.

The growing bones of young children assimilate calcium in the growth process. This occurs particularly in infancy and early childhood where activity may be five times as great as that in adults. Strontium being a bone seeker will concentrate chiefly in young bones and at the present time there is no known method of eradicating such ingested strontium, which has become physiologically fixed in bone. It is in this young age group also that the effects of trauma and bone infections are most common and it is possible that these factors may later influence the development of neoplasia at some later date.

Permissible "body burdens" have been developed for radium but what can be tolerated with strontium is as yet merely an

educated guess. We also do not know whether there is a threshold effect for the development of neoplasms, or whether there is a direct linear dose/effect relationship.

It has been suggested that the safe level of radium is a whole body quantity of 1 microcurie. Taking into account that the $T\frac{1}{2}$ biological of strontium is shorter and the fact that it emits beta rays only, a figure of 5 to 10 times that of radium has been postulated. The medical reasons for this decision may, however, be wrong and it is likely as with other recommendations that they will be lowered as time goes on. It should be stated at this point that it is the somatic manifestations of strontium which is feared and not the genetic effect.

Cs^{137} is of less importance. It has a $T\frac{1}{2}$ biological of some 140 days and a physical $T\frac{1}{2}$ of 33 years. It behaves in the body somewhat similarly to potassium, some of which exists normally in the radioactive form K-40.

If this test is approved, it will be the first nuclear charge to be exploded in Canada, and will be one of the very first explosions devoted to the peaceful uses of atomic energy. It is therefore imperative that adequate pre- and post-shot data be secured for physical as well as medical reasons.

Signed: Donald A. L. Dick,
M.B., Ch.B., D.M.R.T., F.F.R.

Date: August 17, 1959.

DALD/vMcC